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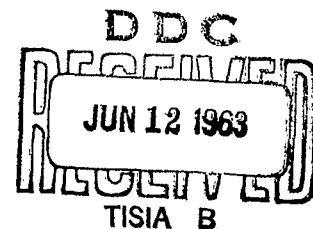
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Material - Titanium - Ti 6Al-4V, Ti 155A

Effect of Heat Treating Media on Mechanical Properties

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Effect of Heat Treating Media on Mechanical Properties

Abstract:

One-half inch diameter Ti 6Al-4V and Ti 155A bar stock was heat treated in an air furnace and in salt bath furnaces containing Park Chemical Co., No. K-33 and E. F. Houghton Co., No. 235 heat treating salts. The Ti 6Al-4V was solution heat treated at 1650°F in the various media for periods ranging one to ninety minutes; the Ti 155A was similarly heat treated at 1450°F. All specimens were machined subsequent to aging at 900°F for 6 hours; heat treat scale contamination thus was eliminated as a test variable. The test results indicated that 10 minute salt bath and 20 minute air furnace solution heat treatments could be used to produce acceptable mechanical properties; these times were in contrast with the generally recommended one hour solution heat treating time, and showed that the solution reactions in the titanium alloys tested were not extremely sluggish.

Reference: Harvey, J. L., Turner, H. C., Sutherland, W. M.,
"Effect of Solution Heat Treating Media on the
Mechanical Properties of 6Al-4V and Ti 155A
Titanium Alloys," General Dynamics/Convair Report
MP 56-235, San Diego, California, 10 January 1957.
(Reference attached).

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A DIVISION OF GENERAL DYNAMICS CORPORATION

SAN DIEGO

ENGINEERING TEST LABORATORIES

REPORT 56-235

DATE 1-10-57

MODEL REA-7162

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REPORT NO. 56-235
EFFECT OF SOLUTION HEAT TREATING
MEDIA ON THE MECHANICAL
PROPERTIES OF 6Al-4V AND
Ti-155A TITANIUM ALLOYS

MODEL REA-7162

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REVISIONS

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ANALYSIS

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REPORT NO. 56-235
**EFFECT OF SOLUTION HEAT TREATING MEDIA ON THE
MECHANICAL PROPERTIES OF 6Al-4V AND Ti-155A
TITANIUM ALLOYS**

PURPOSE:

To determine the effect of solution heat treating media on the mechanical properties of 6Al-4V and Ti-155A titanium alloys.

CONCLUSION:

Considerable reduction in solution heat treating time, below the one hour at temperature used in previous tests, can be accomplished. Solution heat treatment times of 10 minutes in a salt bath and 20 minutes in an air furnace are feasible for light sections.

RECOMMENDATION:

In order to keep atmospheric contamination at a minimum, heat treating in molten salt should be considered for titanium alloy sheet. Further work will be required to define soaking times for various heat treatable titanium alloys.

TEST SPECIMENS AND PROCEDURE:

All the 6Al-4V titanium alloy specimens were taken from 1/2" diameter bar stock of Mallory-Sharon's Heat No. 25066. The 36 specimens cut were 3" long.

All of the Ti-155A titanium alloy specimens were taken from 1/2" diameter bar stock of Titanium Metals Corp. Heat No. M-3171. The 38 specimens cut were 3" long.

The following is the heat treating procedure used on 6Al-4V titanium alloy specimens: Duplicate specimens were solution heat treated at 1650°F. in Park Chemical Co.'s K-33 and E. F. Houghton Co.'s No. 235 titanium heat treating salts for various time intervals. The time intervals used were 1, 4, 8, 16, 32, 64, and 90 minutes. Time was measured from the moment specimens were completely submerged in the molten salt. Duplicate specimens were also solution heat treated in a muffle type air furnace at 1650°F. for various time intervals. The time intervals used were 4, 16, 64, and 90 minutes. Time was measured from the moment the furnace door was closed. All the specimens after solution heat treating were water quenched.

The specimens were then aged at 900°F. for 6 hours and air cooled.

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TEST SPECIMENS AND PROCEDURE: (Cont'd.)

The following heat treating procedure was used on Ti-155A titanium alloy specimens: Duplicate specimens were solution heat treated at 1450°F. * in Park Chemical Co's. K-33 and E.F. Houghton's No. 235 titanium heat treating salts for various time intervals. The time intervals used were 1, 4, 8, 16, 32, and 64 minutes. Time was measured from the moment the specimens were actually submerged in the molten salt bath. Duplicate specimens were also solution heat treated in a muffle type air furnace at 1450°F. for various time intervals. The intervals used were 4, 16, 64, and 90 minutes. Time was measured from the moment the door of the furnace was closed. All the specimens were water quenched after solution heat treatment.

All the Ti-155A specimens were then aged at 900°F. for 6 hours and air cooled.

After the results were obtained on Ti-155A specimens treated as above, further heat treatments were used. Duplicate specimens of Ti-155A titanium alloy were annealed at 1200°F. for 24 hours and air cooled. Another set of duplicate specimens were aged without prior treatment at 900°F. for 6 hours and air cooled.

Duplicate specimens were also left in the "as received" condition.

All the 6Al-4V and Ti-155A titanium alloy specimens were made into standard sub-size tensile specimens.

After machining, the specimens were tested by the Physical Testing Laboratory for the determination of tensile yield strength, tensile ultimate strength, elongation, and reduction of area.

DISCUSSION OF RESULTS:

Results of 6Al-4V titanium alloy tensile tests are tabulated in Table I and presented graphically in Figure 1. It may be noted that there is little change in properties due to solution heat treating time beyond four minutes for any of the heat treating media.

Results of Ti-155A titanium alloy tensile tests will be found in Table II and are plotted in Figure 2. The tensile property vs. solution heat treating time curves are of the same general shape as those for 6Al-4V alloy, except that the properties of specimens heat treated in the air furnace did not level off until 16 minutes solution heat treating time was used. Higher strength was obtained for specimens heat treated in molten salt; the reason for this is not readily evident.

* Titanium Metals Corporation recommends solution treatment at temperatures between 1525 and 1775°F. The 1450°F. treatment used in this test was chosen because some idea of the rate of heat absorption at this temperature was desired.

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SAN DIEGO**PAGE** 3**REPORT NO.** 56-235**MODEL** REA-7162**DATE** 1-10-57**DISCUSSION OF RESULTS:** (Cont'd.)

Ten minutes in molten salt and twenty minutes in an air furnace for 6Al-4V at 1650°F. and Ti-155A at 1450°F. appear to be feasible solution heat treating times for material with a cross-sectional area of 1/2" or less. One hour soak time plus an allowance for specimens to reach furnace temperature has been used in the past. The possibility of shorter soak time and consequent reduction in surface contamination is encouraging for cases where a minimum surface cleanup is desired after heat treatment.

NOTE: The data from which this report was written are recorded in Engineering Test Laboratories Data Book No. 986.

TABLE #1

SPECIMEN NUMBER	HEATING MEDIA	TIME IN YIELD		ULTIMATE ELONGATION		SPECIMEN NUMBER	HEATING MEDIA	TIME IN YIELD		ULTIMATE ELONGATION			
		KSI	%	KSI	%			KSI	%	KSI	%		
94-1	AIR FURNACE	4 MIN.	161.1	178.2	13.5	37.7	K6-11	PARK'S	4 MIN.	162.1	178.4	15.5	31.9
94-2	AT 1650°F	"	166.5	184.9	15.0	45.9	"	AT 1650°F	"	161.4	171.5	17.0	38.2
	A	AVERAGE	163.8	181.6	14.3	41.8	AVERAGE	AT 1650°F	AVERAGE	161.8	178.0	16.3	35.1
94-3		16 MIN.	162.9	181.7	15.0	44.2	K6-13		90 MIN.	166.6	184.1	13.5	42.0
94-4		"	161.0	179.7	15.0	32.6	K6-14	Y	"	166.3	184.5	14.0	48.3
		AVERAGE	162.0	180.7	15.0	40.9	AVERAGE	AT 1650°F	AVERAGE	166.5	184.3	13.8	45.2
94-5		64 MIN.	162.7	181.0	14.0	38.8	H6-1	HUGHTON'S #235	1 MIN.	160.1	178.1	15.0	41.7
94-6		"	162.2	181.1	12.0	36.2	H6-2	AT 1650°F	"	160.5	178.6	14.0	42.0
		AVERAGE	162.5	181.1	13.0	37.5	AVERAGE	AT 1650°F	AVERAGE	160.3	178.4	14.5	41.9
94-7		90 MIN.	161.4	178.9	13.0	39.9	H6-3		4 MIN.	162.9	180.9	14.5	45.9
94-8	Y	"	160.8	179.8	14.0	44.7	H6-4		"	165.0	183.6	16.5	45.3
		AVERAGE	161.1	179.4	13.5	42.3	AVERAGE		AVERAGE	164.0	182.3	15.5	45.6
K6-1	PARK'S K-23	1 MIN.	158.9	176.0	14.0	29.1	H6-5		8 MIN.	165.2	183.3	15.0	45.9
K6-2	AT 1650°F	"	158.5	175.7	20.0	22.8	H6-6		"	164.8	183.6	14.0	39.9
	A	AVERAGE	158.7	175.9	17.0	28.5	AVERAGE		AVERAGE	165.0	183.5	14.5	42.9
K6-3		4 MIN.	161.7	178.5	13.0	35.5	H6-7		16 MIN.	165.4	183.6	13.5	45.9
K6-4		"	161.2	178.5	13.5	51.1	H6-8		"	164.8	183.3	15.5	48.8
		AVERAGE	161.5	178.5	13.3	43.3	AVERAGE		AVERAGE	165.1	183.5	14.5	47.4
K6-5		8 MIN.	164.2	180.6	15.0	31.7	H6-9		32 MIN.	165.8	183.3	15.0	45.4
K6-6		"	161.2	176.1	15.0	39.0	H6-10		"	166.7	185.3	14.0	47.4
		AVERAGE	162.7	178.4	15.0	35.4	AVERAGE		AVERAGE	166.3	184.3	14.5	46.3
K6-7		16 MIN.	163.7	180.4	15.0	51.1	H6-11		64 MIN.	168.5	187.1	13.0	42.3
K6-8		"	164.5	181.7	15.0	45.3	H6-12		"	170.2	187.8	14.0	49.0
		AVERAGE	164.1	181.1	15.0	48.2	AVERAGE		AVERAGE	167.4	187.5	13.5	45.7
H6-7		32 MIN.	162.8	179.2	15.0	51.0	H6-13		90 MIN.	170.2	188.5	13.5	48.7
K6-10	Y	"	160.6	176.8	14.5	44.0	H6-14	Y	"	170.2	188.3	14.5	46.5
		AVERAGE	161.7	178.0	14.8	42.5	AVERAGE		AVERAGE	170.2	188.4	14.0	47.6
NOTE: ALL SPECIMENS SOLUTION HEAT TREATED AT 1650°F, WERE AGED AT 700°F. FOR 16 HOURS.													

TABLE #2

TENSILE PROPERTIES OF TT-155A TITANIUM ALLOY SOLUTION HEAT TREATED AT VARIOUS TIME INTERVALS

SPECIMEN NUMBER	HEATING MEDIA AND TEMPERATURE	TIME IN YIELD, MEDIA	YIELD, KSI	ELONGATION, %	REDUCED WHIPPER	HEATING MEDIA AND TEMPERATURE	TIME IN YIELD, MEDIA	YIELD, KSI	ELONGATION, %	REDUCED WHIPPER
NT-1	AS RECEIVED	162.9	170.1	11.0	40.6	AT-1	162.9	170.1	11.0	40.6
NT-2	"	163.5	170.2	11.0	40.6	AT-2	163.5	170.2	11.0	40.6
		AVERAGE	163.2	170.2	11.0		AVERAGE	163.2	170.2	11.0
NT-3	AIR FURNACE AT 1200°F	24 HRS.	152.6	155.8	18.5	AT-3	152.6	155.8	18.5	42.0
NT-4	"	"	152.8	156.8	19.0	AT-4	152.8	156.8	19.0	44.2
		AVERAGE	152.7	156.3	18.8		AVERAGE	152.7	156.3	43.1
315	AIR FURNACE AT 900°F	6 HRS.	158.7	164.7	16.0	AT-5	158.7	164.7	16.0	35.8
KT-14	"	"	156.7	162.7	16.0	AT-6	156.7	162.7	16.0	34.6
		AVERAGE	157.7	163.7	16.0		AVERAGE	157.7	163.7	35.2
KT-1	PARK'S K-33 AT 1450°F	1 MIN.	166.3	180.3	14.0	AT-7	166.3	180.3	14.0	39.0
KT-2	"	"	166.5	181.8	14.0	AT-8	166.5	181.8	14.0	32.0
		AVERAGE	166.4	181.1	14.0		AVERAGE	166.4	181.1	35.9
KT-3		4 MIN.	167.8	185.2	14.0	HT-1	167.8	185.2	14.0	31.3
KT-4		"	168.7	184.3	14.0	HT-2	168.7	184.3	14.0	35.3
		AVERAGE	168.1	184.8	14.0		AVERAGE	168.1	184.8	33.3
KT-5		8 MIN.	167.0	184.2	15.0	HT-3	167.0	184.2	15.0	34.2
KT-6		"	168.2	186.4	13.0	HT-4	168.2	186.4	13.0	31.3
		AVERAGE	167.6	185.3	14.0		AVERAGE	167.6	185.3	32.8
KT-7		16 MIN.	167.7	185.1	14.0	HT-5	167.7	185.1	14.0	31.8
KT-8		"	167.7	184.7	14.0	HT-6	167.7	184.7	14.0	36.5
		AVERAGE	167.7	184.9	14.0		AVERAGE	167.7	184.9	34.2
KT-9		32 MIN.	168.3	184.9	14.5	HT-7	168.3	184.9	14.5	33.1
KT-10		"	168.0	185.1	14.0	HT-8	168.0	185.1	14.0	30.6
		AVERAGE	168.1	185.0	14.5		AVERAGE	168.1	185.0	31.8
KT-11		64 MIN.	168.3	188.0	14.0	HT-9	168.3	188.0	14.0	30.0
KT-12		"	167.1	187.1	15.0	HT-10	167.1	187.1	15.0	31.1
		AVERAGE	167.7	187.6	14.5		AVERAGE	167.7	187.6	30.6
NOTE:	ALL SPECIMENS SOLUTION HEAT TREATED AT 1450°F, WERE									
	AGED AT 700°F FOR 6 HOURS.									
						HT-11	167.1	184.6	14.0	29.6
						KT-13	167.1	184.6	14.0	29.6
							AVERAGE	167.1	184.6	29.6

FIGURE #1

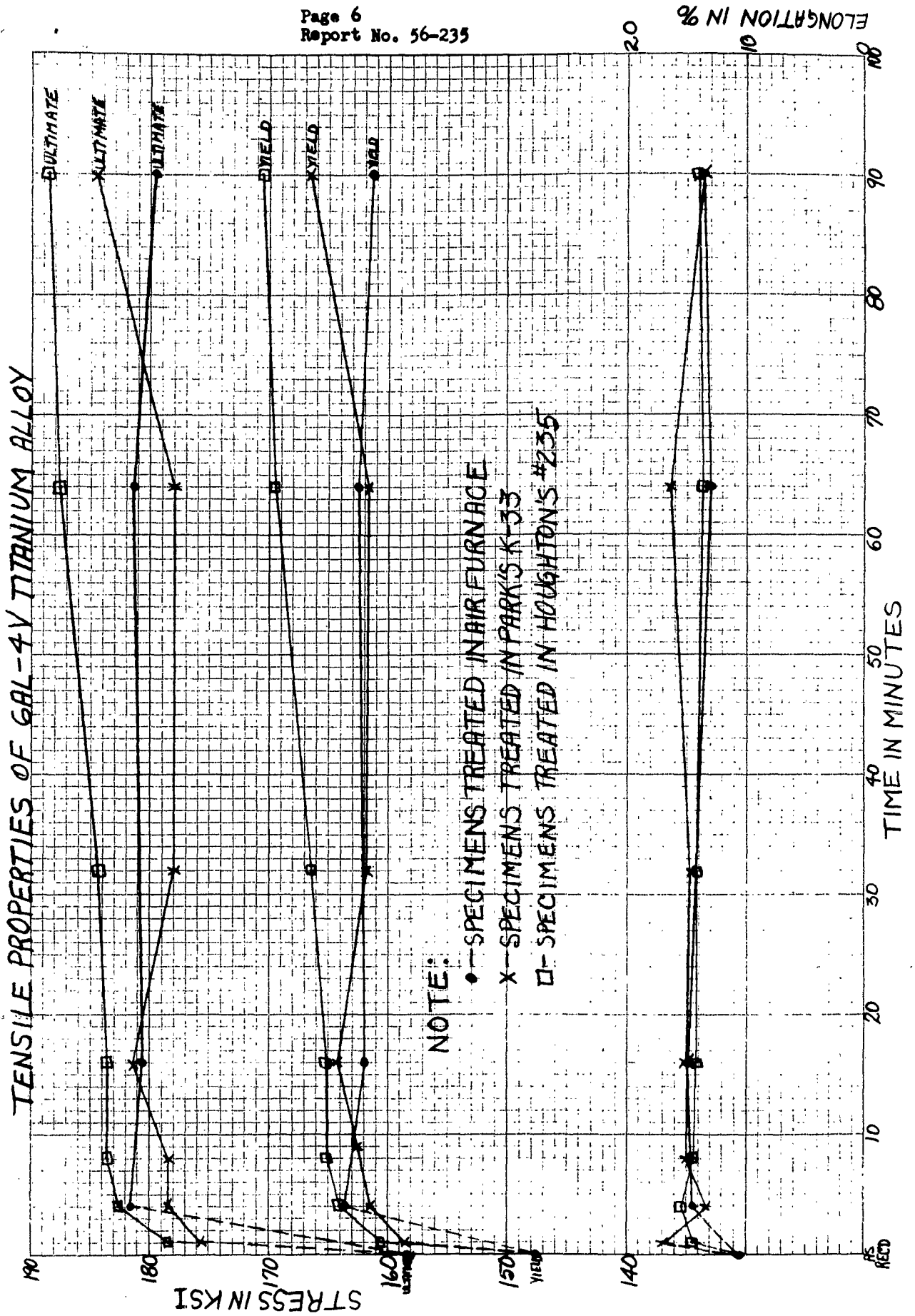


FIGURE #2
TENSILE PROPERTIES OF T-155A TITANIUM ALLOY

